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Elias Loomis

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ORIGINAL ARTICLES.

PROFESSOR ELIAS LOOMIS.*

BY PROFESSOR H. A. NEWTON.

Elias Loomis was born in the little hamlet of Willington, Conn., August 7th, 1811. His father, the Rev. Hubbell Loomis, was pastor in that country parish from 1804 to 1828. He was a man possessed of considerable scholarship, of positive convictions, and of a willingness to follow at all hazards wherever truth and duty, as he conceived them, might lead. He had studied at Union College, in the class of 1799, though apparently he did not finish the college course with his class. He is enrolled with that class in Union College, and he also received, in 1812, the honorary degree of Master of Arts from Yale College. At a later date he went to Illinois, and there was instrumental in founding the institution which afterwards became Shurtleff College.

Although the boy inherited from his father a mathematical taste, yet his love for the languages also was shown at a very early age. At an age at which many bright boys are still struggling with the reading of English, he is reported to have been reading with ease the New Testament in the original Greek. He prepared for college almost entirely under the instruction of

* A memorial address reprinted in part from the *American Journal of Science and Arts*, June, 1890.

his father. He was, for a single winter only, at the Academy at Monson, Mass., and for a short time at Ellington, Conn. Owing in part to feeble health he was more disposed, in those early years, to keep to his books than to roam with other boys over the Willington hills. In later life he frequently said that in his early days he never had a thought of asking what subjects he was most fond of, but studied what he was told to study.

At the age of fourteen he was examined and was admitted to Yale College, but owing to feeble health he waited another year before actually entering a class. In college he appears to have been about equally proficient in all of the studies, taking a good rank as a scholar, and maintaining it through his college course. He graduated in 1830.

A few weeks before graduation he left New Haven and entered a school, Mount Hope Institute near Baltimore, to teach mathematics, and he remained there for a year and a term. One of his classmates, the late Mr. Cone of Hartford, said that Mr. Loomis had intended to spend his life in teaching, and that it surprised him when he heard that this purpose was abandoned, and that Mr. Loomis had gone, in the autumn of 1831, to the Andover Theological Seminary with the distinct expectation of becoming a preacher. This new purpose was, however, again changed when a year later he was appointed tutor in Yale College. A vacancy in the tutorship occurred in the May following (1833), and while not yet twenty-two years of age he returned to New Haven and entered upon the duties of the office. Here he remained for three years and one term. In the spring of 1836 he received the appointment to the chair of Mathematics and Natural Philosophy in Western Reserve College, at Hudson, Ohio. He was allowed to spend the first year in Europe. He was, therefore, during the larger part of the year 1836–7 in Paris attending the lectures of Biot, Poisson, Arago, Dulong, Pouillet and others. He did not visit Germany because of want of money. A long series of letters written by him at this time appeared in the Ohio Observer, and the contrast between England and France as he saw them, and the same places as seen by the tourist to-day is decidedly interesting.

He purchased in London and Paris apparatus for his professorship, and the outfit for a small observatory, and in the autumn of 1837 began his labors at Hudson. Here he remained for seven years, maintaining with unflagging perseverance both his work in teaching and his scientific labors. In judging of this work at Hudson we must remember that he was not with perfect surroundings. He was without an assistant and without the counsel and encouragement of associates in his own branches of science. The financial troubles which culminated in this country in 1837 were peculiarly severe upon the young and struggling college. Money was almost unknown in business circles in Ohio, trade being almost entirely in barter. In this way principally was paid so much of the promised salary of $600 per annum as was not in arrears. In one of his letters he congratulates himself that all of his bills that were more than two years old had been paid. In another he says that there was not enough money in the college treasury to take him out of the state. When he left Hudson the college offered to pay at once the arrears of his salary by deeding to him some of its unimproved lands.

In 1844 he was offered, and he accepted, the office of Professor of Mathematics and Natural Philosophy in the University of New York. In this new position he undertook the preparation of a series of text books in the mathematics, and for some years a large part of the time which he could spare from his regular college work was given to the preparation of these books.

When Professor Henry resigned his professorship at Princeton in order to accept the office of Secretary of the Smithsonian Institution, Professor Loomis was offered the vacant chair. He went to Princeton and remained there during one year, at the end of which he was induced to return again to his old place in the University of New York. Here he continued until 1860, when he was elected to the Professorship in Yale College made vacant by the death of Professor Olmsted. For the last twenty-nine years of his life, he here labored for the college and for science, passing away on the 15th of August, 1889.

A subject of which he early undertook the investigation was *Terrestrial Magnetism.* We often use the rhetorical phrase "True as the needle to the pole," but, looked at carefully, the magnetic needle is anything but constant in direction; like the weather vane on the steeple, it is ever in motion, swinging back and forth, in motions minute and slow it is true, but still always swinging. It has fitfully irregular motions;—it has motions with a daily period;—motions with an annual period; and motions whose oscillations require centuries for completion.

The *daily* motions of the magnetic needle were those which Tutor Loomis first studied. At the beginning of the second year of his tutorship he set up by the north window of his room in North College a heavy wooden block, and on it the variation compass that belongs to the college. Here for over thirteen months, he observed the position of the needle at hourly intervals in the day time, his observations usually being for seventeen successive hours of each day.

The results of these observations, together with a special discussion of the extraordinary cases of disturbance, were published in the *American Journal of Science* in 1836. No similar observations of the kind made in this country had at that time been published. So far as I am aware, none made before 1834 have since been published, except ten days observations made by Professor Bache in 1832. In fact, I know of only one or two like series of hourly observations made in Europe earlier than these by Tutor Loomis. He also at this time formed the purpose of collecting all the observations of magnetic declination that had been hitherto made in the United States, and of constructing from them a magnetic chart of the country. He appealed successfully to the Connecticut Academy of Arts and Sciences for its sympathy and aid. The work of collecting facts was so far advanced before leaving New Haven that when he had been a few months Professor at Hudson, he forwarded to the *American Journal of Science* a discussion of the observations thus far obtained, and with them a map of the United States, with the lines of equal deviation of the needle drawn upon it. Two years later he published additional observations and a revised edition of this map.

These were the first published magnetic charts of the United States, and though the materials for their construction were not numerous, and in many cases those obtainable were not entirely trustworthy, yet sixteen years later, when a map was made by the United States Coast Survey from later and more numerous data, Professor Bache declared that between his own new map and that of Professor Loomis, when proper allowance had been made for the secular changes, the "*agreement was remarkable.*"

The northern end of a perfectly balanced magnetic needle turns downward, and the angle it makes with the horizon is called the magnetic *dip*. This angle is an important one, and is observed with accuracy only by using an expensive instrument, and taking unusual pains in observing. Hence only a few observations of this element were found by Professor Loomis. From these, however, he ventured to put on his first magnetic map a few lines that exhibited the amount of the *dip*.

While he was in Europe he purchased a first class dipping needle, for Western Reserve College, and at Hudson and the neighborhood in term time, and at other places in vacation, he made observations with this needle. Some of these observations were made before his second magnetic chart was published, and upon this map were now given tolerably good positions of the lines of equal magnetic dip. But he continued his observations for several years, determining the dip at over seventy stations, spread over thirteen states, each determination being the mean of from 160 to over 4,000 readings. These observations were published in several successive papers in the transactions of the American Philosophical Society at Philadelphia.

Various papers on terrestrial magnetism, in continuation of his earlier investigations, appeared in 1842, in 1844, in 1847, and in 1859, but movements in Germany, England and Russia had meanwhile been inaugurated which led to the establishment by governments of a score of well equipped magnetic observatories, and this subject passed largely out of private hands.

Closely connected with terrestrial magnetism, and to be considered with it, is the *Aurora Borealis*. In the week that

covered the end of August and the beginning of September, 1859, there occurred an exceedingly brilliant display of the Northern Lights. Believing that an exhaustive discussion of a single aurora promised to do more for the promotion of science than an imperfect study of an indefinite number of them, Professor Loomis undertook at once to collect and to collate accounts of this display. A large number of such accounts were secured from North America, from Europe, from Asia, and from places in the Southern Hemisphere; especially all the reports from the Smithsonian observers and correspondents, were placed in his hands by the secretary, Professor Henry.

These observations and the discussions of them were given to the public during the following two years, in a series of nine papers in the *American Journal of Science.*

Few, if any, displays on record were as remarkable as was this one for brilliancy and for geographical extent. Certainly about no aurora have there been collected so many facts. The display continued for a week. The luminous region entirely encircled the North Pole of the earth. It extended on this continent on the 2d of September as far south as Cuba, and to an unknown distance to the north. In altitude the bases of the columns of light were about fifty miles above the earth's surface, and the streamers shot up at times to a height of five hundred miles. Thus over a broad belt on both continents this large region above the lower atmosphere was filled with masses of luminous material. A display similar to this, and possibly of equal brilliancy, was at the same time witnessed in the Southern Hemisphere.

The nine papers were mainly devoted to the statements of observers. Professor Loomis, however, went on to collect facts about other auroras, and to make inductions from the whole of the material thus brought together. He showed that there was good reason for believing that not only was this display represented by a corresponding one in the Southern Hemisphere, but that all remarkable displays in either hemisphere are accompanied by corresponding ones in the other.

He showed also that all the principal phenomena of electricity were developed during the auroral display of 1859; that light was developed in passing from one conductor to

another, that heat in poor conductors, that the peculiar electric shock to the animal system, the excitement of magnetism in irons, the deflection of the magnetic needle, the decomposition of chemical solutions, each and all were produced during the auroral storm, and evidently by its agency. There were also in America effects upon the telegraph that were entirely consistent with the assumption previously made by Walker for England, that currents of electricity moved from northeast to southwest across the country. From the observations of the motion of auroral beams, he showed that they also moved from north-northeast to south-southwest, there being thus a general correspondence in motion between the electrical currents and the motion of the beams.

When there is a special magnetic disturbance at any place, there is usually a similar one at all other neighboring places. But these disturbances do not occur at the several places at the same instant of time. Professor Loomis showed that in the United States they take place in succession as we go from northeast to southwest, the velocity of the wave of disturbance being over one hundred miles per minute. The waves of magnetic irregularities were thus connected with the electrical current and with the drifting motions of the streamers in the auroral display.

As incident to this discussion, he collected all available observations of auroras, and he deduced from them the annual number of auroras visible at each place of observation. These numbers, when written upon a chart of the Northern Hemisphere, showed that auroras were by no means equally distributed over the earth's surface. It was found that the region in which they occurred most frequently was a belt or zone of moderate breadth and of oval form, enclosing the North Pole of the earth, and also the North Magnetic Pole. It was therefore much farther south in the Western hemisphere than in the Eastern. Along the central line of this belt there are more than eighty auroras annually, but on going either north or south from the central line of that belt the number diminishes.

In 1870 Professor Loomis published a paper of importance relating to terrestrial magnetism, in which he showed its

connection and that of the aurora with spots on the sun. That the spots on the sun had periods of maximum and minimum development had long been known. Lamont had noticed a periodicity in the magnetic diurnal variations. Sabine and Wolf and Gauthier had noticed that the two periodicities were allied. The connection of the period of solar spots with conjunction and opposition of certain planets had been shown by De La Rue and Stewart. Professor Loomis undertook an exhaustive examination of the facts that tended to confirm or refute the propositions that had been advanced. He confirmed and added to the conclusions of Messrs. De La Rue and Stewart. He also brought together such facts as were relevant to the question, and he showed that the regular diurnal variation of the magnetic needle was entirely independent of the solar spots, but that those disturbances that were excessive in amount were almost exactly proportional to the spotted surface of the sun. He also showed that great disturbances of the earth's magnetism are accompanied by unusual disturbances on the sun's surface on the very day of the storm.

Various forms of periodicity in the aurora have frequently been suggested. Professor Loomis, from all available accounts of the aurora, was able to show that while in the center of the zone of greatest auroral frequency auroras might be visible nearly every night, and hence that periodicity could not easily be shown by means of numbers of auroras recorded in such places, yet that such periodicity was distinctly traceable at places where the average number seen was about twenty or twenty-five a year. The times of maxima and minima of the solar spots were seen to correspond in a remarkable manner with the maxima and minima in the frequency of auroral displays in these middle latitudes. Also from the daily observations made by Messrs. Herrick and Bradley at New Haven during seventeen years, he concluded that auroral displays in the middle latitudes of America are generally accompanied by an unusual disturbance of the sun's surface on the very day of the aurora. The magnetism of the earth, the Aurora Borealis, and the spots on the sun, have thus all three a causal connection, and apparently that connection is closely related to the conjunctions and oppositions of certain planets.

Shortly after the publication of this memoir, Professor Lovering published his extensive catalogue of auroras. A further discussion of the periodicity of the auroras was undertaken by Professor Loomis and published in 1873. In this he made use of all the auroras recorded in Professor Lovering's catalogue. They confirmed his previous conclusions, only slight modifications being required by the new facts presented, and by their more systematic collation.

In these papers, as in most of his papers upon other subjects, Professor Loomis was ever intent upon answering the questions: What are the laws of nature? What do the phenomena teach us? To establish laws which had been already formulated by others, but which still needed confirmation, was to him equally important with the formulation and proof of laws entirely new.

The science of *Meteorology* has, however, been that in which Professor Loomis has made the most important contributions to human knowledge.

Shortly after his graduation in 1830 and before he entered upon the tutorship, there appeared the first of a long series of papers by Mr. Redfield, of New York City, upon the theory of storms. In the last year of his tutorship there appeared also the first of a like remarkable series of papers on the same subject by Professor Espy of Philadelphia. Two rival theories were advocated by these two men, and these theories became the subject of no little discussion in scientific meetings, and in scientific journals, for a long period of years. Professor Loomis had, from their very inception, taken a warm interest in these discussions, and the subject of meteorology, and in particular its central problem the theory of storms, held in his thought and work the first place from that time to the day of his death.

In his visit to Europe the year before he went to Hudson, he purchased a set of meteorological instruments, and for several years in Hudson he steadily performed the naturally irksome task of making twice each day a complete set of meteorological observations. A few weeks after he entered upon his professorship in Hudson a tornado passed five miles from that place, and he went out immediately to examine the track and learn

what facts he could that should bear upon the theory of the tornado. The results were valuable, but he was not altogether satisfied with them. They led him, however, to undertake the discussion of one of the large storms that covered the whole United States.

For this purpose he selected the storm which had occurred near the 20th of December, 1836. Sir John Herschel had recommended that hourly observations be taken by all meteorological observers on four term days in the year, that is, observations for thirty-six successive hours at each equinox and each solstice. This storm fell partly upon one of these term days. Professor Loomis set to work to collect all the meteorological observations made during the week of the storm that he could obtain from all parts of the United States, and from some stations in Canada. The discussion resulting therefrom was read in March, 1840, before the American Philosophical Society at Philadelphia.

Let us for a little while consider the amount of knowledge of the facts about storms in our possession in 1840, the date when this memoir was read and an abstract of it published in Philadelphia. Franklin had noted the motion of storms from southwest to northeast. He said:* "Our northeast storms in North America begin first in point of time in the southwest parts, that is to say, the air in Georgia, the farthest of our colonies to the southwest, begins to move southwesterly before the air of Carolina, which is the next colony northeastward; the air of Carolina has the same motion before the air of Virginia, which lies still more northeastward; and so on northeasterly through Pennsylvania, New York, New England, etc., quite to Newfoundland." Redfield had traced several storms along the West India Islands northwesterly until about in the latitude of 30° their course was turned quite abruptly and they swept off northeasterly along the Atlantic coast toward and even past Newfoundland. Espy found some storms moving easterly or south of east from the Mississippi to the Atlantic.

Brandes had announced as a law that the wind in storms blows inward toward a center; but his law was an induction

* Letter to Alexander Small, May 12, 1760.

from a small number of observations. Dove had contended for a whirling motion; Redfield advanced facts to show that the winds blew in circles anti-clockwise around a center that advanced in the direction of the prevalent winds, and with him agreed Reid, Piddington and others. Espy, agreeing with Brandes, claimed that the observations in the various storms showed a centripetal motion of the winds, toward a center if the region covered by the storm was round, and toward a central line if the storm region was longer in one direction than in another. Espy's conclusions were intimately connected with his theory that in the center of the storm there was an upward motion of the air, and that the condensation of vapor into rain furnished the energy needed for the continuation of the storm. The rival theories of Redfield and Espy were in sharp contest on several points, but the main contention was around this central question: Do the winds blow in circular whirls, or do they blow in toward a center? New York State was collecting observations from the Academies. The American Philosophical Society and the Franklin Institute, aided by an appropriation from the State of Pennsylvania, had united in an effort to learn the facts and the true theory of storms.

Under such circumstances the thorough discussion of a single violent storm was likely to add materially to our knowledge. The treatment of this storm by Professor Loomis was probably more complete than that of any previous one, and the methods which he employed were better fitted to elicit the truth than any earlier methods. But the storm was a very large one, extending from the Gulf of Mexico to an unknown distance north, and having its center apparently to the north of all the observers. The results which he was able to secure did not sustain either of the two rival theories, but rather tended to prove some features in each of them. Professor Loomis was not himself satisfied with them, and he therefore waited for another storm that should be better fitted for examination.

In the month of February, 1842, a second tornado passed over northeastern Ohio, and Professor Loomis with one of his colleagues again started out for the examination of the track.

The tornado passed over a piece of woods, and hence the positions of the prostrate trees showed clearly the motion of the wind in the passing tornado, and threw much light upon the character of this kind of storm. But the tornado was a single feature of a large storm that covered the whole country, and a second storm of great intensity was also experienced in the same month.

The discussion of these two storms was now undertaken by him. The paper giving the results of that discussion was sent to Professor Bache, and read by him at the centennial meeting of the American Philosophical Society, in May, 1843, and created, as Professor Bache wrote, a great sensation. It was at the time important for the light which it threw upon the rival contending theories of Espy and of Redfield, but it was more important by far by reason of the new method of investigation then for the first time employed.

In the paper upon the storm of 1836 Professor Loomis had made some advance upon previous methods of representing the facts about storms. But even the method he then used was entirely unfitted to give answers to the questions which meteorologists were asking. Some of those questions were stated in circulars issued by the joint committee of the American Philosophical Society and the Franklin Institute: What are the phases of the great storms of rain and snow that traverse our continent; what their shape and size; in what direction, and with what velocity do their centers move along the surface of the earth; are they round, or oblong, or irregular in shape; do they move in different directions in different seasons of the year?

The graphic representation by Professor Loomis on the map of the United States of the storm of 1836 had been a series of lines drawn joining the places where at a given hour the barometer was at its lowest point. That line would so far as the barometer was concerned mark for that hour the central line of the storm. The progress of the line from hour to hour on the map showed, quite imperfectly, how the storm had traveled. Some arrows added showed to the eye also certain facts about the movements of the air.

Professor Espy adopted and thereafter adhered to a modification of this method of representing storm phenomena, and I think meteorologists will agree with me in my opinion that Professor Espy's four reports from 1842 to 1854 though they contained an immense accumulation of facts, were because of this radical defect of presentation almost useless to meteorological science.

In the discussion of the storms of 1842, instead of the line of minimum depression of the barometer, Professor Loomis drew on the map a series of lines of equal barometric pressure, or rather of equal deviations from the normal average pressure for each place. A series of maps representing the storm at successive intervals of twelve hours were thus constructed, upon each of which was drawn a line through all places where the barometer stood at its normal or average height. A second line was drawn through all places where the barometer stood $\frac{2}{10}$ of an inch below the normal; and other lines through points where the barometer was $\frac{4}{10}$ below, $\frac{6}{10}$ below, $\frac{8}{10}$ below, etc.; also lines were drawn through those points where the barometer stood $\frac{2}{10}$, $\frac{4}{10}$, $\frac{6}{10}$, etc. above its normal height. The deviations of the barometric pressure from the normal were thus made prominent, and all other phenomena of the storm were regarded as related to those barometric lines. A series of colors represented respectively the places where the sky was clear, where the sky was overcast, and where rain or snow was falling. A series of lines represented the places at which the temperature was at the normal, or was 10 or 20 or 30 degrees above the normal, or below the normal. Arrows of proper direction and length represented the direction and the intensity of the winds at the different stations. These successive maps for the three or four days of the storm furnished to the eye all its phenomena in a simple and most effective manner.

You have no doubt, most of you, already recognized in this description the charts, which to-day are so common, issued by the United States Signal Service, and by weather service bureaus in other countries. The method seems so natural that it should occur to any person who has the subject of a storm under consideration. But the greatest inventions are ofttimes

the simplest, and I am inclined to believe that the introduction of this single method of representing and discussing the phenomena of a storm was the greatest of the services which our colleague rendered to science. This method is at the foundation of what is sometimes called "the new meteorology," and the paper which contains its first presentation stands forth, I am convinced, as the most important paper in the history of that science. I regret that I cannot aid my memory by quoting the exact words, but I remember distinctly what seemed to me an almost despairing expression made many years ago by one who had high responsibility in the matter of meteorological work, as he looked out upon the confused mass of observations already made, and felt unable to say in what direction progress was to be expected. With this I contrast the buoyant expressions of another officer charged with like responsibility, as he showed me, one or two decades later (in 1869), charts constructed like those of Professor Loomis, and said, "I care not for the mass of observations made in the usual form. What I want is the power and the material for making such charts as these." These two expressions of Sir George Airy and of LeVerrier mark the progress and the direction of progress in meteorology developed by Professor Loomis's memoir.

What was his own judgment of the method at the time of its publication and its value in meteorology, can be seen from his words at the close of the memoir, which I beg permission to quote.

"It appears to me that if the course of investigations adopted with respect to the two storms of February, 1842, was systematically pursued we should soon have some settled principles in meteorology. If we could be furnished with two meteorological charts of the United States daily for one year, charts showing the state of the barometer, thermometer, winds, sky, etc., for every part of the country, it would settle forever the laws of storms. No false theory could stand against such an array of testimony. Such a set of maps would be worth more than all which has been hitherto done in meteorology. Moreover, the subject would be well nigh exhausted. But one year's observation would be needed. The storms of one year are probably

but a repetition of those of the preceding. Instead then of the guerilla warfare which has been maintained for centuries with indifferent success, although at the expense of great self-devotion on the part of individual chiefs, is it not time to embark in a general meteorological crusade? A well arranged system of observations spread over the country, would accomplish more in one year, than observations at a few insulated posts, however accurate and complete, continued to the end of time. The United States are favorably situated for such an enterprise. Observations spread over a smaller territory would be inadequate, as they would not show the extent of any large storm. If we take a survey of the entire globe, we shall search in vain for more than one equal area which could be occupied by the same number of trusty observers. In Europe there is opportunity for a like organization, but with this incumbrance, that it must needs embrace several nations of different languages and governments. The United States then afford decidedly the most hopeful field for such an enterprise. Shall we hesitate to embark in it; or shall we grope timidly along as in former years? There are but few questions of science which can be prosecuted in this country to the same advantage as in Europe. Here is one where the advantage is in our favor. Would it not be wise to devote our main strength to the reduction of this fortress? We need observers spread over the entire country at distances from each other not more than fifty miles. This would require five or six hundred observers for the United States. About half this number of registers are now kept in one shape or another, and the number by suitable efforts might probably be doubled. Supervision is needed to introduce uniformity throughout, and to render some of the registers more complete. Is not such an enterprise worthy of the American Philosophical Society? The general government has for more than twenty years done something, and has lately manifested a disposition to do more for this object. If private zeal could be more generally enlisted, the war might soon be ended, and men would cease to ridicule the idea of our being able to predict an approaching storm."

This plan of a systematic meteorological campaign was cordially seconded by Professors Bache and Peirce. At a some-

what later date the American Academy of Sciences of Boston appointed a committee, of which Professor Loomis was chairman, to urge upon the proper authorities the execution of the plan. The American Philosophical Society of Philadelphia united its voice with that of the Academy. About this time Professor Henry was made Secretary of the Smithsonian Institution. He determined to make American meteorology one of the leading subjects of investigation to be aided by the Institution. At Professor Henry's request Professor Loomis prepared a report upon the meteorology of the United States, in which he showed what advantages society might expect from the study of the phenomena of storms; what had been done in this country toward making the necessary observations, and toward deducing from them general laws; and finally, what encouragement there was to a further prosecution of the same researches. He then presented in detail a practicable plan for securing the hoped-for advantages in their fullest extent.

This plan looked to a unifying of all the work done by existing observers, a systematic supervision, a supplementing of it by new observers at needed points, a securing of the coöperation of the British government and the Hudson's Bay Company in the regions to the north of us, and finally a thorough discussion of the observations collected. A siege of three years was contemplated. In the history of the several steps that finally led to the establishment of the United States Signal Service, this report has an important place.

The scheme laid down by Professor Loomis was in part followed out by the Institution. But the fragmentary character of the observations, the want of systematic distribution of the places of the observers, and the imperfections of the barometers, made the material collected difficult of discussion. Professor Loomis waited in hopes of some better system.

In 1854, Professor Loomis undertook a rediscussion of the storm of 1836, using the new methods introduced for treating the storms of 1842. A visit to Europe shortly after enabled him to collect a large number of observations upon a storm or series of storms that occurred in Europe about a week later than that American storm. He had long been anxious to connect, if possible, these two storms, as he said, "stepping across

the Atlantic." The European and the American storms, however, not only proved to be distinct one from the other, but the discussion showed clearly that many of the laws of American storms were radically different from those of the European storms. The results of the whole discussion were published in 1859 by the Smithsonian Institution.

Upon coming to New Haven, in 1860, he commenced the collection of all the meteorological observations that had been made in New Haven and the immediate vicinity, and succeeded in finding sets which, when brought together, made up a nearly continuous record through 86 years. The results of these observations formed the subject of a memoir published by the Connecticut Academy of Arts and Sciences in 1866.

It became part of his duties in college to deliver a course of lectures upon the subject of meteorology. In preparation for these he caused to be printed in very limited numbers the outlines of a treatise upon meteorology, to be used as the basis of his series of lectures. In 1868 he developed this outline into a treatise suited to use in college classes and in private study. This treatise, notwithstanding the rapid advances of the science during more than twenty years, is still indispensable to the student of meteorology.

The better system of observing, for which Professor Loomis had been long waiting, came when the United States Signal Service was established in 1871. The daily maps of the weather published by the Bureau were constructed essentially after the plan which Professor Loomis had, thirty years before, invented for the treatment of the storms of 1842. As soon as these maps had been been published for the two years 1872 and 1873, Professor Loomis commenced in earnest to deduce from them the lessons which they taught us respecting the nature and the phenomena of United States storms. To this investigation he gave nearly all his energies during the remaining fifteen years of his life.

For several years he employed and paid for the services of assistants whose time was given to the preparation of material for use in his studies. The aggregate cost of this assistance was of itself a very large contribution to science. Beginning in April, 1874, he presented regularly at eighteen successive

meetings of the National Academy of Sciences in April and in October of each year, a paper entitled "Contributions to Meteorology." These were at first based upon the publications of the Signal Service alone, but as years went by like publications appeared in Europe that were useful for his work. These papers were published in July and January following the Academy meeting, and they regularly formed the first and leading article in eighteen successive volumes of the *American Journal of Science*. Gradually, one after another of his college duties were committed to others that he might give his whole strength to these investigations.

An attack of malaria interrupted the regularity of the series. His advancing years and diminishing strength warned him that the end of his investigations could not be far distant. The number of hours in which he could work each day was slowly diminishing. Five more papers followed at somewhat less regular intervals.

In 1884 he began a revision of the whole series of papers. They had been presented without much regard to systematic order in the subjects investigated, and new material had accumulated from time to time, so that a thorough, systematic revision seemed absolutely necessary.

In 1885 he presented to the Academy of Sciences the first chapter of this revision, in which he discussed the areas of low pressure—their form, their size, their motions, and the phenomena attending them. Two years later, in 1887, the second chapter of the revision appeared, in which he discussed the areas of high pressure, their form, magnitude, direction and velocity of movement, and their relation to areas of low pressure. Gradually his physical strength was failing, though his mind was as bright and clear as ever. To this work, the only work which he was now doing, he was able to give two or three hours a day. Anxiously he husbanded his strength, slowly and painfully preparing the diagrams and the tables for the third chapter upon rain areas, the phenomena of rainfall in its connection with areas of low pressure, and the varied phenomena of unusual rainfall. "I see," he said to a friend, "not the end of this subject, but where I must stop. I hope I shall have strength to finish this work, and then I shall be ready to die."

This third and finishing chapter was finally passed through the printer's hands and some advance copies distributed to correspondents abroad in the summer months of 1889. His work upon the theory of storms he felt was finished. As he paid the bill of the printer, he said to him: "When I return at the close of the vacation I expect to put into your hands for printing a new edition of the 'Loomis Genealogy.'" Before the close of the vacation he died.

These three chapters of his revised edition of "Contributions to Meteorology," constitute the full and ripe fruitage of his work in his favorite science. They will for a long time to come be the basis of facts by which writers in theoretical meteorology must test their formulas. They cover all the important points taken up in the twenty-three earlier memoirs,—with one important exception, the relation of mountain observations to those made on the plains below. The laws connecting these two are not yet clearly indicated; much remains to be learned about them, and they are of the utmost importance in theoretical meteorology. He felt most deeply the backward steps taken by the United States Signal Service when mountain observations and the publication of the *International Bulletin* were discontinued. "The National Academy of Sciences," he said, "ought at once to take up the subject and use all its influence to secure the restoration of these two services."

Professor Loomis at various times studied certain other questions in physics and astronomy that were more or less allied with the subjects to which he gave the principal part of his time, and he published the results of his studies. He made a series of experiments on currents of electricity generated by a plate of zinc buried in the earth. He examined the electrical phenomena in certain houses in New York; the curious phenomena of optical moving figures; the vibrations sent out from waterfalls as the water flows over certain dams; the orbits of the satellites of Uranus; the temperature of the planets; the variations of light of the stars η Argus and Algol; and the comet of 1861.

In 1840 he married Miss Julia E. Upson, of Talmadge, Ohio, a lady about whom those who knew her have spoken to me only in terms of praise, and for whose memory Professor

Loomis cherished a tender reverence. She died in 1854, leaving two sons. From this time Professor Loomis lived in apartments, surrounded by his books and devoted to his studies. His sons after passing their school and college days went to their own fields of work. During many years of his New Haven life he was unable to receive visitors in the evening. He made very few new friends, and one after another of his old ones passed away. To his work he was able to give undivided his time and his strength. His mind did not seem to require the excitement of social intercourse for its full and healthful activity. Isolated though he was there was in him no trace whatever of selfish or morbid feeling. In council his advice was always marked by his clear judgment of what was important, and at the same time what was practicable. Whatever he himself had the right to decide was promptly decided by a yes or a no, and few persons cared to question the finality of his decision. But when his colleagues, or others, had the right to decide he accepted their decision without questioning or subsequent murmur. Upon being told that his letters to Mr. Herrick had come to the College Library, and that he could, if he chose, examine them and see whether there were among them any which he would prefer not to leave in this *quasi* public place, he promptly replied: "No, I never wrote a letter which I should be ashamed to see published."

After coming to New York he had a generous income from his books, besides his salary as professor. The amount he saved from his income was carefully and prudently invested, and before his death the savings with their accumulations were a large estate, how large only he and his banker knew.

One of his college classmates told me that Mr. Loomis left college with the definitely expressed purpose that the world should be better for his living in it. The central proposition in his inaugural address at Hudson in 1838 was: "That it is essential to the best interests of society that there should be a certain class of men devoted exclusively to the cultivation of abstract science without any regard to its practical applications; and consequently that such men instead of being a dead weight upon society are to be ranked among the greatest benefactors

of their race." He chose this for his principal work for man, and he steadily kept to the chosen work. To establish an Astronomical Observatory had been through life a cherished object. He entered into and aided heartily the plans of Mr. Winchester, both before and after Mr. Winchester asked his Trustees to transfer his magnificent endowment to the University. Professor Loomis looked forward to a large institution in the future on the observatory site. To endow this public service, after making liberal provision for his two sons, he bequeathed his estate. The income from more than $300,000 will eventually be available to continue the work of his life. With clear judgment of what was most important he limited the use of that income to the payment of salaries of persons whose time should be exclusively devoted to the making of observations for the promotion of the science of astronomy, or to the reduction of astronomical observations, and to defraying the expenses of publication. He knew that if he provided observers, other benefactors would furnish buildings, and instruments, and the costs of supervision and maintenance.

RAINFALL IN MICHIGAN—JULY.

BY N. B. CONGER,
Director State Weather Service.

The average rainfall for July for the state is 3.32 inches, a decrease of 0.56 inch from the average of June. It will be noticed by reference to the chart that the heaviest rainfall occurs in the southern section, and along the west coast of the state into the upper peninsula, where the average is a little over three inches. It is apparent that the prevailing southwest winds of this month must have a strong effect on the rainfall, for it keeps a uniform amount along the west shore, which would indicate that the moist winds from Lake Michigan deposited most of this and it was not carried very far into the interior portion of the state. It will also be noticed by the normal amount at the different points indicated on the chart that the amount decreases as it approaches the east shore, with the exception of Alpena county.

Relative to heavy rainfalls for this month it would seem that the state is not subject to excess in rainfall, as rainfalls


MICHIGAN WEATHER SERVICE.
In co-operation with the U.S. Signal Service,
PRECIPITATION CHART.
July Normal.
13 YEARS OBSERVATIONS
LAKE SUPERIOR
ISLE ROYAL
WISCONSIN
LAKE HURON
LAKE MICHIGAN
INDIANA
OHIO
Scale of Shades
Schoolcraft
Mackinac
Chippewa
Delta
Iron
Marquette
Menominee
Emmet
Cheboygan
Presque Isle
Charlevoix
Otsego
Montmorency
Alpena
Kalkaska
Crawford
Oscoda
Alcona
Roscommon
Ogemaw
Iosco
Osceola
Clare
Gladwin
Arenac
Huron
Saginaw Bay
Bay
Oceana
Newaygo
Mecosta
Isabella
Midland
Tuscola
Sanilac
Montcalm
Gratiot
Saginaw
Kent
Genesee
Lapeer
St. Clair
Ottawa
Ionia
Clinton
Shiawassee
Oakland
Macomb
Allegan
Barry
Eaton
Ingham
Livingston
Van Buren
Kalamazoo
Calhoun
Jackson
Washtenaw
Wayne
Cass
St. Joseph
Branch
Hillsdale
Lenawee
Monroe
Lake Erie
279
288
296
279
296
296
326
266
292
330
385
308
281
387
381

of over five inches have occurred on an average but twice in thirteen years, and are more liable to occur in the southwestern portion of the state than elsewhere. The records from the counties of Berrien, Branch, Hillsdale and St. Joseph go to bear out this, and it seems to be an established fact.

In many cases these heavy rainfalls are from thunder storms, and a large amount of rain will be deposited in one storm. In the central section the average amount of rainfall is much less than in the southern, and the section seem to be more liable to light rainfalls than to excesses, and, with the exception of a portion of Kent and Lapeer counties, the average is about 2.85 inches. In the northern section, the east side of the state receives about one quarter of an inch less than the west side with the exception of a small portion round about Alpena.

The rainfall for this month is necessarily more of a local character than for the preceding month, as few general storms pass over the state during the month of July, and therefore but little rainfall of a general character occurs. It is mostly deposited in local showers or heavy thunderstorms, which prevail in the state, and are found to be more frequent in the southwest and along the west shore than at other portions of the state. The moisture ladened winds from the west are unloaded almost as soon as they strike the west coast from Lake Michigan, so that by the time they reach the east side of the state they are dry, and, consequently, it is found that light rainfall is more prevalent on the east side of the state than the west.

TORNADO OBSERVATIONS.

BY PROFESSOR H. A. HAZEN.

As the tornado season is passing it is of some importance that all who are likely to encounter one should have some idea of what observations are most needed. It is a remarkable fact that, after fifty years' study and observations, we know hardly a single fact regarding these outbursts. A careful study of all the literature has shown the most contradictory statements regarding the simplest phenomena and such as one would think ought to be established by this time beyond all question. This is a matter in which every one ought to be interested and if such will take pains to record a few simple facts and send them

to their own State Weather Service or the Signal Office in Washington they may do great good. The following are some of the points to be noted:

1. Time. This is very important and should be recorded to the nearest minute, stating also whether the time used is Central, Eastern or any other.

2. The existence of a funnel cloud and how far off it was when first seen. All pictures of this cloud (which it is feared are largely imaginary) show it to be a definite, black cloud and one that ought to be seen many miles away, whereas, it is generally seen only when close to the observer. Is this non-visibility due to a cloud of dust which precedes the funnel, or how can it be accounted for?

3. Are there two separate clouds seen to the northwest and southwest which seem to come together? If so, how distinct or well defined are they?

4. If a roar is heard, give the interval between its first audibility and the appearance of the funnel, by a watch.

5. What is the direction toward which the storm moves?

6. What is the width of the track proper? Care should be taken to carefully estimate the width of the greatest destruction and not that to which roofs are blown off or tree branches broken.

7. What is the appearance of the sky as respects lightning and of the funnel as respects electrical appearance, lightning or glow?

8. Is there any rain immediately before the tornado? This does not refer to a general rain, but a violent rain evidently accompanying the tornado.

9. Is there any sudden rain or hail just after the tornado? There seems to be the gravest doubt on this question of rain before or after the tornado, and attention should be specially directed to this point.

10. If hail occurs it is important to know whether it falls in streaks or otherwise, the size and shape of stones, etc.

11. Is there a *whirl* in the cloud, and which way around? This is one of the most important facts of all to be ascertained. If one is south of the funnel, or more than 1,000 feet away, there is little use in looking for evidence of a whirl, but attention should be fixed on other things. If one is on the north side he should fix his eyes closely on the ground or a few feet above it, and see if any branches, timbers, leaves, etc., are carried to his

right hand, that is, in the direction from which the tornado has come. If one is near enough he should run with the utmost speed possible to the rear of the tornado, and see if any flying debris are carried to his right hand. After the tornado has passed, make a most careful examination of the north side and see if any trees or objects have been bent over toward the west or southwest. In any case the most important part of the track to be studied and described is that to the north of the center. It is believed that nearly all the contradictions have arisen from a neglect of this distinction.

12. What is the fluctuation of air-pressure? This may be regarded as the most important point to be settled at present. A barograph trace would be on all accounts the most important evidence that could be presented. Nearly all *authorities* declare that "corks are violently expelled from empty bottles." This would be a most satisfactory proof if it could be obtained. It is a most remarkable fact that no record of such an event has ever been published, when we consider how many hundreds and thousands of times it ought to have occurred. Such expulsion is to be looked for most frequently in wide mouthed bottles and with oily corks. It is not at all necessary that the bottle be empty. Let all the houses over which or near which tornadoes pass be carefully examined for evidence of this kind and we ought to have overwhelming proof in a single year whether such a thing ever occurs. Of course glass stoppers and wired corks would show no effect.

13. Are timbers or movable objects carried up in the funnel? Care should be taken to note how the motion takes place, whether simultaneously, end over end, or more regularly.

14. Are chickens or fowls stripped of their feathers? Do they live afterward? Is there any evidence of this depluming where the fowl is not carried a long distance.

15. Are any persons killed? If so, their names.

16. What is the loss from the direct destruction to buildings, but not to growing crops, orchards, etc.

These are a few of the more general questions, but others who may study such storms will find many things not given here which should be recorded.

TORNADOES IN FLORIDA.

STATE TORNADO CHARTS.—FLORIDA.

By LIEUT. JNO. P. FINLEY, SIGNAL SERVICE, U. S. A.

TABLE I.—*Tornadoes in Florida.*

Period of observation, 18 years,—1871-1888.

Total number of storms,—10.

Year of greatest frequency, 1877, 1882 and 1886,—2 storms each.

Average yearly frequency,—0.6 storms.

Year in past (10) ten years, no report of storms,—1879, 1880, 1883, 1884, 1887 and 1888.

Month of greatest frequency, September,—3 storms.

Day of greatest frequency, September 10th,—2 storms.

Hour of greatest frequency,—Afternoon.

Month without storms,—January, February, March, June, August and December.

Prevailing direction of storm movement,—NE.

Region of maximum storm frequency,—northeastern portion.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Florida for a period of 18 years, from 1871 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Suwannee	November 5.	1875	1:58 p. m.	NE.		
Escambia	April 7.	1877	Night.	NE.	Funnel.	1,320.
Wakulla	May 6.	1877	Afternoon.		"	2,640.
Levy	September 10.	1878	"			
Leon	October 28.	1881	"			
Alachua	September 9.	1882	9 p. m.	NE.	Funnel.	600.
Baker	September 10.	1882	10:55 p. m.	E	Pear shaped.	
Alachua	October 11.	1885	12 m.	ENE.		900.
Escambia	July 13.	1886	3:50 p. m.	E.	Cylindrical.	1,200.
Monroe	July 26.	1886	7 p. m.		Waterspout.	

TABLE III.—*Relative frequency of Tornadoes by months and days, for Florida.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
April	7	1	1
May	6	1	1
July	13 and 26	2	2
September	9 and $(10)^2$	2	3
October	11 and 28	2	2
November	5	1	1
Total		9	10

to their own State Weather Service or the Signal Office in Washington they may do great good. The following are some of the points to be noted:

1. Time. This is very important and should be recorded to the nearest minute, stating also whether the time used is Central, Eastern or any other.

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right hand, that is, in the direction from which the tornado has come. If one is near enough he should run with the utmost speed possible to the rear of the tornado, and see if any flying debris are carried to his right hand. After the tornado has passed, make a most careful examination of the north side and see if any trees or objects have been bent over toward the west or southwest. In any case the most important part of the track to be studied and described is that to the north of the center. It is believed that nearly all the contradictions have arisen from a neglect of this distinction.

12. What is the fluctuation of air-pressure? This may be regarded as the most important point to be settled at present. A barograph trace would be on all accounts the most important evidence that could be presented. Nearly all *authorities* declare that "corks are violently expelled from empty bottles." This would be a most satisfactory proof if it could be obtained. It is a most remarkable fact that no record of such an event has ever been published, when we consider how many hundreds and thousands of times it ought to have occurred. Such expulsion is to be looked for most frequently in wide mouthed bottles and with oily corks. It is not at all necessary that the bottle be empty. Let all the houses over which or near which tornadoes pass be carefully examined for evidence of this kind and we ought to have overwhelming proof in a single year whether such a thing ever occurs. Of course glass stoppers and wired corks would show no effect.

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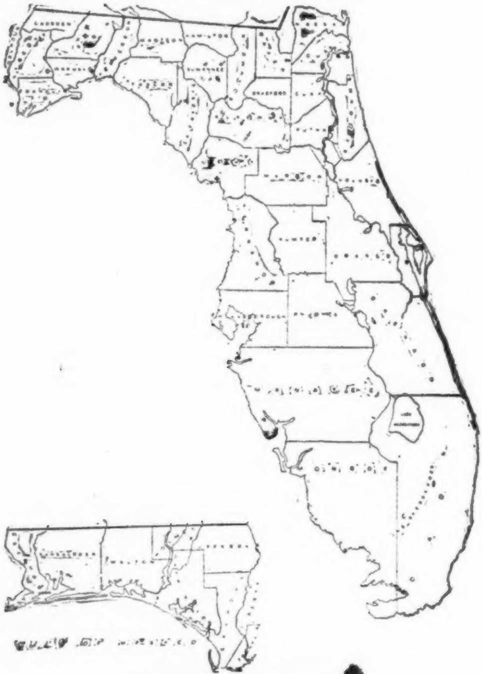
15. Are any persons killed? If so, their names.

16. What is the loss from the direct destruction to buildings, but not to growing crops, orchards, etc.

These are a few of the more general questions, but others who may study such storms will find many things not given here which should be recorded.



TORNADOES IN FLORIDA.

STATE TORNADO CHARTS.—FLORIDA.

By LIEUT. JNO. P. FINLEY, SIGNAL SERVICE, U. S. A.

TABLE I.—*Tornadoes in Florida.*

Period of observation, 18 years,—1871-1888.
Total number of storms,—10.
Year of greatest frequency, 1877, 1882 and 1886,—2 storms each.
Average yearly frequency,—0.6 storms.
Year in past (10) ten years, no report of storms,—1879, 1880, 1883, 1884, 1887 and 1888.
Month of greatest frequency, September,—3 storms.
Day of greatest frequency, September 10th,—2 storms.
Hour of greatest frequency,—Afternoon.
Month without storms,—January, February, March, June, August and December.
Prevailing direction of storm movement,—NE.
Region of maximum storm frequency,—northeastern portion.

TABLE II.—*A Chronological Table, showing the location, date and time of occurrence, and general character of formation and movement of Tornadoes in the State of Florida for a period of 18 years, from 1871 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Suwannee	November 5.	1875	1:58 p. m.	NE.	....	....
Escambia	April 7.	1877	Night.	NE.	Funnel.	1,320.
Wakulla	May 6.	1877	Afternoon.	....	"	2,640.
Levy	September 10.	1878	"	....	"	....
Lean	October 28.	1881	"	....	....	....
Alachua	September 9.	1882	9 p. m.	NE.	Funnel.	600.
Baker	September 10.	1882	10:55 p. m.	E	Pear shaped.	....
Alachua	October 11.	1885	12 m.	ENE.	....	900.
Escambia	July 13.	1886	3:50 p. m.	E.	Cylindrical.	1,200.
Monroe	July 26.	1886	7 p. m.	....	Waterspout.	....

TABLE III.—*Relative frequency of Tornadoes by months and days, for Florida.*

The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
April	7	1	1
May	6	1	1
July	13 and 26	2	2
September	9 and $(10)^2$	2	3
October	11 and 28	2	2
November	5	1	1
Total		9	10

STATE TORNADO CHARTS.—SOUTH CAROLINA.*

By Lieut. Jno. P. Finley, Signal Service, U. S. A.

Table I.—*Tornadoes in South Carolina.*

Period of observation, 128 years,—1761-1888.
Total number of storms,—73.
Year of greatest frequency, 1884,—27 storms.
Average yearly frequency,—2.6 storms.
Year in past ten (10) years, no report of storms, 1881 and 1882.
Month of greatest frequency, March—17 storms.
Day of greatest frequency, February 19th,—12 storms.
Hour of greatest frequency,—4 to 5 P. M.
Months without storms,—October.
Prevailing direction of storm movement,—NE.
Region of maximum storm frequency,—central and northwest portions.

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* The Chart was printed in Vol. VI. on page 322.

TABLE II.—*A Chronological Table showing the location, date and time of occurrence and general character of formation and movement of Tornadoes in the State of South Carolina, for a period of 128 years, from 1761 to 1888.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Charleston	May 4.	1761	2:30 p. m	NE.	Funnel.	1,800.
Charleston	September 20.	1811				
Charleston	September 10.	1811	12:30 p. m.	NW. ?	Cone.	300.
Beaufort	July 1.	1814	3 p. m.	NE.		300.
Richland	April 25.	1819				
Abbeville	April 15.	1827				
Charleston	May 7.	1831	Evening.			
Sumter	May 13.	1835				
Saint Luke's (town)	March 18.	1840		E.		300.
Newberry	September 30.	1848	4:30 p. m.	SE.	Funnel.	600.
Abbeville	March —.	1849		E 10° S.	"	
Spartanburgh	August 28.	1851			"	
Greenville	March —.	1856				
Spartanburgh	September 17.	1858	3 p. m.	NNE.		225.
Abbeville		1859		NE.		
Anderson	March 23.	1865	6 p. m.	SE.		450 to 900.
Oconee	April —.	1865		SE.		900.
Chester	April 18.	1872		NE.	Funnel.	
Darlington		1874		E.		300.
Harry	March 20.	1875	5:40 p. m.	NE.	Funnel.	
Abbeville and Edgefield	May 1.	1875	5 p. m.	NE.	"	
Barnwell	"	1875	6:30 p. m.	SE.	"	
Lexington	August 14.	1876	Afternoon.	SE.	"	1,320.
Spartanburgh	June 3.	1878	5:30 p. m.			
Chesterfield	September 12.	1878	Afternoon.	NE.	Funnel.	300.
Fairfield	March 22.	1879		E.	"	1,320.
Lexington	April 16.	1879	3:30 p. m.		Inverted funnel.	
Colleton	"	1879	3:45 p. m.	NE.	Funnel.	600 to 2,700.
Charleston	"	1879	Afternoon.	ENE.		
Edgefield	April 6.	1880	5 p. m.	NE.		
Richland	April 29.	1880	4 p. m.	NE.		300 to 800.
Richland	July 5.	1880		NE.		
Barnwell	April 22.	1883	4 p. m.	NE.	Balloon.	
Sumter	April 23.	1883	6:50 p. m.	E.	Funnel.	300 to 2,400.
Williamsburgh	February 19.	1884	11 p. m.	NE.	"	300 to 1,320.
Williamsburgh	"	1884	10 p. m.	NE.	"	1,320.
Lexington, Fairfield and Chester	"	1884	6:30 p. m.	NNE.	"	600 to 3,960.

TABLE II.—*Concluded.*

County.	Month and Day.	Year.	Time.	Direction.	Form of Cloud.	Width of Path in Feet.
Greenville and Spartanburgh	February 19.	1884	4 p. m.	NE.	Funnel.	
Fairfield	"	1884	6 p. m.	NE.	"	1,200 to 1,800.
Chester	"	1884	"	NE.	"	1,200 to 1,800.
Edgefield, Newberry and Fairfield	"	1884	"	NE.	"	300 to 5,280.
Darlington	"	1884	11 p. m.	E.	"	900.
Abbeville, Fairfield and Chester	"	1884	4 p. m.	NE.	"	150 to 1,800.
Anderson, Spartanburgh and York	"	1884	"	NE.	"	150 to 2,640.
Aiken	"	1884	8 p. m.	E 40° S.	"	600.
Aiken	"	1884	7 p. m.	NE.	"	750.
Greenville	February 27.	1884	12 m.	NE.	"	
Darlington	March 10.	1884	11 p. m.	NNE.	"	300.
Richland	March 24.	1884	4:30 a. m.	E.	"	
Richland	"	1884	Evening.			
York	March 25.	1884	6 p. m.	NE.	Funnel.	450.
Anderson and Spartanburgh	"	1884	4 p. m.	NE.	"	600 to 1,000.
Lexington	"	1884	5 p. m.	NE.	"	
Laurens	"	1884	"	NE.	"	
Spartanburgh	"	1884	4 p. m.	NE.	"	
Greenville	"	1884	7 p. m.	NE.	"	2,640.
Spartanburgh	"	1884	p. m.			
Oconee	March 26.	1884	"	NE.	Funnel.	
Aiken	April 14.	1884	7 p. m.		"	60 to 600.
Marion	July 9.	1884	4:30 p. m.	ENE.	Hour glass.	3,300.
Clarendon	December 22.	1884	5 p. m.	NE.	Funnel.	1,200.
Spartanburgh and York	May 27.	1885	3 p. m.	ENE.	"	450 to 600.
Spartanburgh	November 7.	1885	10 a. m.		Whirlwind.	90.
Darlington	July 1.	1886	Afternoon.	NE.	Funnel.	
Pickens	January 23.	1887	"	E.	"	2,640.
Greenville	"	1887	"	ENE.	"	2,640.
Spartanburgh	January 30.	1887	9 p. m.	NE.	"	1,320.
Laurens	July 29.	1887	9:30 a. m.	NE.	"	150 to 500.
Lexington	August 18.	1888	5:30 p. m.	NE.	"	300.
Anderson	"	1888	4:40 p. m.	NE.	"	300 to 5,000.
Laurens	September 15.	1888	6 p. m.	NE.	"	1,320.
Anderson	"	1888	5 p. m.	NE.	"	1,320 to 2,640.
Marion	September 21.	1888	6:30 p. m.	Easterly.	"	1,800.

TABLE III.—*Relative frequency of Tornadoes by months and days, for South Carolina.*
The index figures to the right and above the dates show how many times tornadoes occurred on that day of the month.

Month.	Day of Month.	No. of Days.	Total No. of Tornadoes per month.
January	(23)^2 and 30	2	3
February	(19)^{12} and 27	2	13
March	10, 18, 20, 22, 23, (24)^2, (25)^7, 26 and (—)^2	9	17
April	6, 14, 15, (16)^3, 18, 22, 23, 25, 29 and (—)	10	12
May	(1)^2, 4, 7, 13 and 27	5	6
June	3	1	1
July	(1)^2, 5, 9 and 29	4	5
August	14, (18)^2 and 28	3	4
September	10, 12, (15)^2, 17, 20, 21 and 30	7	8
November	7	1	1
December	22	1	1
(—) Blank	(—)^2	0	2
Total		45	73

NOTE.—The (—) signifies date missing

TROMBES AND TORNADOES.

By H. Faye,
Membre de l'Institut, Président du Bureau des Longitudes, etc.

(CONTINUED FROM JULY NUMBER.)

Barnard Tornado.—Another tornado overturned the house of Mr. Turner, whose family took refuge in a cabin at a safe distance from the trajectory. The house was situated at the right and it is shown that the debris was projected in the aforesaid sectors. Farther on, Mr. Finley, struck by the whirling character of the winds, studied their direction by the debris of the houses of Messrs. Moore and Senion, situated one to the north, the other to the south of the trajectory. In this figure, the probable winds and the winds which occurred, turned around this center.

A third chart relative to this tornado is not less significant, although it contains little capable of falling in opposite directions, except a hay-rick and railroad ties.

Delphos Tornado.—This is one of the best studied tornadoes: it merits careful examination. It made its appearance in Kansas, May 30, 1879, in the afternoon. Its trajectory, sensibly rectilinear, was directed from SW to NE, cutting perpendicularly the direction of the prevailing light wind. Mr. McLaren, whose house was so situated that the phenomenon could be seen from its beginning, said that a light rain accompanied by hail began to fall toward two o'clock. A half hour later the tornado showed itself in the SW in the form of a *trombe*, advancing rapidly toward the NE. A little before its appearance, the cloud from which it seemed to descend manifested a violent agitation. A series of little appended cones formed there, hanging from the clouds like rags. During ten minutes they appeared and disappeared like merry dancers.

Finally, one of these appendages seemed to enlarge, elongate and absorb the others. This was the *trombe* mentioned above, which formed and descended, turning with great rapidity from right to left. It oscillated vertically without reaching the ground and seemed to sway from side to side.

When the tornado was not more than three or four miles distant it already touched the earth, and the sound of it could be heard distinctly. It crossed Salt Creek and reached the property of Mr. Rathgiber, in Ottawa County. The house was a

half mile from the trajectory of the center; it had only its roof removed. Farther on it was the turn of Mrs. Sophronia Clark's house which was just in the way of the passage of the center. This edifice, of a story and a half, was raised from its foundation and transported to the northeast for a distance of ninety feet. There it fell a shapeless mass of ruins, which were immediately dispersed towards all the points of the compass.

The house of Mr. T. Potter, built of cut stone, was destroyed, the roof carried off, the walls falling on the spot. The family having taken refuge in cellars escaped the disaster.

The house of Mr. Samuel McBride, four miles from Delphos, was next attacked. Taken entire from its foundation it was first carried ten feet towards the north, then twelve feet farther to the northwest; its debris was scattered over a semi-circle from sixty to eighty yards in diameter. It was situated near the trajectory on the north side. A laborer was seen frightened at the approach of the storm to leave the house and run to the northeast. After the storm he was observed with great surprise, returning hobbling from the opposite direction. The unfortunate man having been caught by the tornado and thrown to the southwest. (See the sector $s'D'u'$ of Figure 2).

Mr. King's house (to the south of the trajectory) was next attacked. It was taken entire from its foundation and carried three hundred feet farther to the east-northeast, and deposited on the bank of the river. Curiously enough, damaged as it was, it escaped complete ruin. The tornado then had a diameter of one and three-fourth miles. Cotton-wood trees three feet in diameter were broken close to the ground, others which were weaker were twisted like cords. Then came the house of Mr. Taylor (north side of the trajectory) torn from its foundation and transported to the southwest twenty-five rods. The family sheltered in the cellar escaped the disaster. After having demolished the house and barns of Mr. Volkman, broken his wagons and carts, and agricultural machines, the tornado attacked the property of Mr. Krone. He saw it coming, now mounting in the air, contracting itself, and then descending to the ground dilating again. Mr. Krone waited until it was a half mile from his house; then, judging that the house would be destroyed, he with his family sought safety in flight. Unfortunately they ran to the northeast, exactly in the direction of the tornado. They were soon caught. The house was already destroyed when Mr. Krone, wounded in the head and body by

the debris of the house, thrown to the earth, rolled and raised up by turns, was stopped by some obstacle. The eldest daughter of Mr. Krone was carried two hundred yards towards the northeast, thrown against a fence and killed at once. She was found quite naked, covered with a coating of black mud. Mr. Krone's second daughter had the hip nearly pierced through by a piece of wood. From her wound, seven inches wide, the physician extracted fragments of wood, mud, nails and straw. All the other members of the family were overtaken by a similar fate. Here, as always, women suffered most. Entirely denuded of their clothing they were at the mercy of the debris which blew in every direction. Their hair was so plastered with mud that it was necessary to shave their heads. Several animals were transfixed by pieces of wood; a house cat was thrown half a mile to the northeast. The axle of a wagon with the wheels were thrown to the northeast about a half mile, etc.

Here I must pause a moment to make an important remark. It has been seen by what has preceded, and will be seen more clearly in following the examination farther, that the objects or debris situated to the north of the trajectory are thrown to the southwest, or at least in the sector $S'D'U'$ of Figure 2, opened to the southwest, while the contrary takes place with the debris of houses situated south of the trajectory. These are projected to the northeast. It was this last direction which was taken by Mr. Krone's house; everything, men, animals, debris of all sorts, was thrown towards the northeast. Now, on Mr. Finley's chart I find that the house of Mr. Krone, situated very near the trajectory, was a little to the north of that line. It is impossible, moreover, to take advantage of the anomaly in favor of the centripetal theory, for the projection of the Krone family would be inexplicable. It must be concluded from this, I think, that there has been a slight error in tracing the trajectory of the tornado, or, rather that the engraving of the tornado (noted above) made it deviate a little from its course, a deviation which has not been taken into account in drawing a straight line between the true extreme points of its course.

There is nothing in the minute observations of these storms to indicate the existence of those centripetal currents, which meteorologists believe to have an existence around cyclones. Certainly if they are to be found anywhere, it would be at the foot of these tornadoes, to which is attributed so energetic an aspiration.

Action upon Forests.—"If we think a moment we shall see that even if a perfect vacuum should surround a stone or a tree* it would remain immovable. . . . Even if this vacuum extended to the limits of the atmosphere, the condition would still remain.†" It cannot be known, then, how a tornado aspires trees and tears them up. If it tears them up it would be in the action of an ascending current of improbable violence. In fact it does not tear them up: it breaks or beats them upon the ground with enough violence to uproot them. It throws them down in the sector sDu, Figure 2, (p. 86), when they are south of the central trajectory, in sector $s'D'u'$, if they are placed to the north. The upper part of a tree, projected to a certain distance in the direction of a tornado, may be taken again a few minutes after by the gyration and thrown still further. But no one has ever seen a tree thus detached from the ground carried into a *trombe* by ascending currents, and raised, whirling, to its mouth. Otherwise tornadoes would be seen carrying in the air parts of the forests which they traverse, and in letting them fall to the ground further on, they would realize the fable of Macbeth.

That which has just been said applies to the trees situated in an open country. In a forest it would happen rather differently. There the trees are mown down, as it were, the whole width of the trajectory of the tornado. It looks as if a road or regular avenue had been made in the forest, except that it is encumbered by fallen trees. And these remarkable effects are not peculiar to the tornadoes of the United States: the *trombes* of Europe do as much in our forests. In Sweden and Norway they level pine trees, in France the oak and elm, in the Southern States of the Union, the cottonwood. But in forests trees are not thrown down in the area of the sectors sDu, $s'D'u'$, of Figure 2; the direction Du and $D'u'$ are suppressed, in a way, by the resistance of the trees situated outside of the tornado, and forming the two borders of the path devastated. All the trees are found thrown toward the center of the avenue which, at first sight, seems to prove the centripetal hypothesis.

The Carrying of Heavy Debris to Great Distances.—Some assertions on this subject deserve a separate examination. Such are those which I found in the article already cited, by Mr. Douglas Archibald.

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* I have used tree instead of *stick*.

† Hazen, AMERICAN METEOROLOGICAL JOURNAL, July, 1889, p. 102.

"In the official report of the Iowa and Illinois tornado of May 22, 1873, different witnesses say that they saw boards whirling around in the funnel . . . . saw rails flying out from the summit (of the column). An average rail weighs about forty pounds, and we may close this list with one quoted by Ferrel as a well authenticated case, in the tornado of Mount Carmel, June 4, 1877, in which the spire, vane and gilded ball of the Methodist church were carried fifteen miles to the north-eastward. The whole evidence, in fact, both in tornadoes and in their milder form of water and sand spouts, is overwhelmingly against M. Faye's views, and in favor of upward motion, and aspiration to their very summits." The real question to be explained is how these witnesses were able to see, through the walls which are opaque and impenetrable to vision, boards circulate during a tornado, and bars of iron escape from a summit which is always hidden by clouds. There is nothing more in the last assertions: the vane and gilded ball of a church tower were found fifteen miles away toward the northeast. There could be no illusion there.

Without doubt this singular transportation could be explained as Mr. Ferrel has explained it, in admitting that the ball was carried up by the tornado and sustained during fifteen or twenty minutes by the ascending air. In this case, in attributing to the ascending air a sufficient velocity (139 *m.* per second), in admitting that the ball participated exactly in the movement of translation without participating in the interior gyration, the *trombe* progressing at the rate of a mile a minute could have carried the ball and the spire fifteen miles to the northeast. There is nothing there which could offend any one, habituated to seeing *trombes* transporting enormous masses of water in their cloud sheaths, as in the case of those which lower the water level of lakes by a meter. The fact can be explained in a more simple way, by the successive impulsions which the ball, at first falling to the right of the trajectory, would have received from the tornado, nearly in the same direction, that is, toward the northeast. The gyrations of the tornado are much more rapid than its movement of translation. The ball will be thrown ahead at each encounter, and will fall at a certain distance toward the northeast. There it will be taken up again by the tornado and again thrown. The singularity of the fact consists in that these impulsions should be repeated rather often upon a territory free from obstacles. But it is only in this

connection that the fact is really exceptional. To show that these suppositions are not extravagant I will cite a recent case, that of the tornado which ravaged the commune of Jongul (department of the Doubs) the 13th of last July. The following is the account written by Dr. Jounod who visited the western part of this "windfall" (see *Comptes rendus* of the Academy of Sept. 16.)

"The effects produced by an intensity which is much greater on the right than on the left side of the current, prove in an evident manner that the two currents have not exactly the same power; which is clearly explained by M. Faye in his theory, according to which the most powerful effects are on the right, where the velocity of translation is added to the velocity of gyration, while on the left the velocity of translation is subtracted from the velocity of gyration.

"The trees broken and crushed to the ground are generally seen on the right side and are often projected to great distances. To cite only one example of it, I have seen a pine tree .85 meters in diameter broken short at 2.5 meters from the ground; the part detached had been thrown 20 meters ahead and to the right; in falling it was broken again into three parts, and the largest part, having a mean diameter of .50 of a meter, and a length of 9 meters and having large branches, was transported 30 meters farther ahead and upon the center (of the trajectory). The other two parts seemed to have received a series of blows in different directions, and stopped short of the preceding."

A ball would lend itself still better than a tree trunk to impulsions of this character, and upon a suitable surface it might possibly traverse the enormous distance of fifteen miles.

(TO BE CONTINUED).

CONCERNING THERMOMETERS.

By Professor W. A. Rogers.

[CONTINUED].

It would obviously be unsafe to draw definite conclusions from the results obtained from particular thermometers or from comparisons made under special conditions. An examination, however, of the data in the second of the typical cases given, will indicate the general character of the pulsatory movements of a mercurial column which have been found to occur to a greater

or less extent in nearly all of the thermometers investigated. We may, therefore, draw provisional conclusions from these results and then test their value by subsequent observations made under widely different conditions. These conclusions may be stated as follows:

(a) The pulsatory movements which take place in a mercurial column under uniform variations of temperature are recurrent in their character. Under certain conditions this recurrent action is so well defined that the movement becomes a real harmonic. Its general character is nearly the same under a uniformly falling temperature as under a uniformly rising temperature. Whatever tends to destroy uniformity in the increments of temperature has a tendency to break up the harmonic movement of the column; hence at the commencement of a forced rise or fall of temperature and when comparisons are made in agitated liquids, the harmonic character of the pulsations becomes much less evident. In the case of liquid contacts, however, much depends upon the quantity of the liquid employed and upon the method and the extent of the agitation. When the thermometers compared are immersed in a large body of water which is kept in *continual* agitation by means of paddle wheels, the pulsatory movements of the column become so irregular that they mask and probably destroy any harmonic movement which might occur under other circumstances.

It must be understood at the outset of this discussion that the problem is a very complex one. The phenomena observed may be due to causes yet unknown, but we may at least conjecturally assign the following:

(1) The peculiar character of the thermometers under investigation.

(2) The personal equation of the observer in estimation fractions of sub-divisions of the scale of degrees.

(3) The different effects of a uniform rise or fall of temperature upon different thermometers.

(4) The effect of a previous thermal condition of the bulb as compared with that of the stem.

(5) The combined effect of any or all of these conditions.

It is, however, to be especially noted that when the object is to obtain the real temperature of an object with which the thermometer is in contact, *e. g.*, a bar of metal upon which are traced limiting lines which define a standard of length; it makes no difference whether the phenomena observed can be traced to the

observer or is in some way connected with the thermometers themselves. In either case, any error of a periodic character which may appear in the observations, should be eliminated by extending the comparisons at uniform intervals over the entire time required for a complete cycle of changes to take place.

(b) The amplitude, or the range between the greatest and the least values of a given series of differences between two thermometers compared at equal intervals of time, is nearly independent of the time required for the completion of the cycle of changes *inter se* and is also nearly a constant under wide variations of temperature. It seems, moreover, to be independent of the method of exposure, except for deep immersion in liquids. I have generally found the numerical value of this constant decidedly less for bulbs having a cylindrical than for those having a spherical form.

Resumé of Observations for Amplitude.

Date.	Interval in Minutes.	Change of Temperature.	Amplitude.	Means.
1503 and 2292 in an iron box.				
		°	°	
May 3	14	0.51	0.19	
5	12	.52	.18	
8	23	.46	.18	
9	8	.50	.15	
20	12	.39	.17	
21	123	.58	.17	
			——	0.17
In an iron box surrounded with water.				
May 23	17	0.32	0.13	
26	44	.37	.17	
28	32	.88	.17	
29	30	.47	.17	
30	26	.54	.17	
			——	0.16
1503 and 2292 in water tank.				
June 2	120	1.04	0.14	
3	220	.55	.14	
4	200	.70	.12	
5	320	.48	.12	
7	210	.52	.13	
9	310	.42	.15	
10	244	.50	.15	
11	38	.45	.18	
12	645	.43	.14	
13	53	.44	.17	

Date.	Interval in Minutes.	Change of Temperature.	Amplitude.	Means.
		°	°	
June 13	360	.91	.16	
14	130	.23	.17	
			——	0.15
Suspended in air.				
June 24	8	.43	0.14	
30	27	.48	.16	
31	9	.45	.15	
July 1	9	.51	.16	
			——	0.15
On bed of Comparator. Position—Horizontal.				
July 2	80	.46	0.20	
3	73	.62	.18	
7	42	.72	.17	
			——	0.18
Amplitude of 217122.				
June 30	30	0.74	0.32	
	20	1.09	.34	
	16	1.05	.31	
	23	1.02	.34	
			——	0.33
Amplitude of 6672.				
June 30	30	0.71	0.33	
	20	1.02	.35	
	16	.92	.33	
	23	.98	.38	
			——	0.35

The constancy of this element will appear from the preceding tabular values derived from the comparisons of the Signal Office Standard, Green No. 1503, with my own standard Green No. 2292, and with the Signal Office sub-standards, Green No. 6672 and Hicks No. 17,122.

Since the relations between 2292 and 1503 will be referred to subsequently, their values are given at this point for intervals of 5°. They depend upon a large number of comparisons made under conditions calculated to secure an elimination of systematic errors, and arranged in groups of single degrees. The values given in the following table were obtained by taking the means of the deviations for each degree of the groups of 5°. The corrections given in the third column were determined by Mr. Russell of the Signal Office from a comparison of 1503 with an air thermometer. The values here given were derived from a curve constructed from the data kindly communicated me by the Chief Signal Officer.

Absolute Corrections to Thermometers, Green No. 1503 and Green No. 2292.

Temperature.	Number of comparisons with 2292.	Corrections to 1503 communicated from the Signal Office.	Corrections to 2292 from random observations.	Corrections from comparisons by cycles.	Temperature.	Number of comparisons with 2292.	Corrections to 1503 communicated from the Signal Office.	Corrections to 2292 from random observations.	Corrections from comparisons by cycles.
°		°	°	°	°		°	°	°
Fahr. −19	157	−.078	−.052	......	Fahr. +41	60	+.010	+.010	−.010
−14	61	−.068	−.068	......	+46	80	−.006	+.012	−.016
− 9	112	−.060	−.042	......	51	216	−.022	+.006	−.006
− 4	111	−.068	−.024	......	56	344	−.038	+.026	+.018
+ 1	189	−.086	−.056	......	61	262	−.058	−.006	+.000
+ 6	286	−.090	−.064	......	66	138	−.074	−.020	−.034
+11	238	−.080	−.052	......	71	252	−.090	−.028	−.018
+16	191	−.068	−.052	......	76	158	−.084	−.036	−.030
+21	69	−.044	−.032	......	81	82	−.072	−.024	−.030
+26	106	−.018	−.018	......	86	42	−.080	−.032	−.044
+31	3	+.006	−.036	......	91	56	−.094	−.018	−.048
+36	64	+.020	−.002	......	96	26	−.110	−.080	−.096

(c) The progress of the mercurial column is, in general, delayed while passing under the graduations on the stem and it is accelerated at a point between the adjacent graduations which is determined by some element connected with the particular thermometer in use. Attention is at this point again called to

the fact that the question in regard to the reality of this movement concerns only its physical explanation. It makes no difference whether the apparent motion is subjective or real. Its effect in introducing an actual error at given points of the scale as compared with the reading at any point taken as a standard, cannot be neglected in observations of precision.

I can hardly resist the conviction that the phenomenon has a physical cause. My assistant, Mr. E. C. Teague of the Senior class of Colby University, has made a careful series of observations in this connection and his results agree well with my own. These observations have an exceptional value, since they were made without a previous knowledge of the phenomena in question.

Similar results were obtained from a series of readings of a tenth degree thermometer of Jena glass made by Professor C. H. McLeod and the writer during the last meeting of the American Association at Toronto. Professor McLeod's readings immediately followed my own, the interval between the reading of each observer being one minute. The extent of the delay in passing under the graduations and the point of recovery will appear from the following data:

On account of a lack of space, the readings are limited to the space required for the completion of three cycles of changes, but essentially the same movements were kept up for a period of two hours.

	Observer.			Observer.	
Time. h. m.	R. °	M. °	Time. h. m.	R. °	M. °
3 11	25.22	25.21	3 29	25.04	25.03
12	.20	.21	30	.03	.02
13	.21	.21	31	.03	.01
14	.21	.20			
15	.20	.20	3 43	24.90	24.90
16	.20	.17	44	.90	.90
17	.17	.16	45	.90	.90
18	.16	.15	46	.90	.90
19	.15	.12	47	.90	.90
20	.13	.12	48	.90	.90
21	.12	.10	49	.90	.89
22	.10	.10	50	.89	.88
23	.10	.09	51	.88	.86
24	.09	.09	52	.87	.86
25	.09	.08	53	.86	.85
26	.08	.08	54	.85	.85
27	.07	.08	55	.84	.85
28	.08	.04	56	.84	.83

(d) The evidence of a sudden movement of the column between the graduations was very marked in the second of the typical cases given, but the readings themselves do not always exhibit this action, since the spring forward often occurred between the readings separated by an interval of one minute. I do not see how I could have been mistaken in repeatedly observing the column after it reached a nearly stationery position at about six-tenths of the distance between the degree marks, *quiver* for a moment, preparatory to a spring forward. If the phenomenon in question is in some way connected with the surface tension of the mercury at the meniscus, its explanation will easily appear. An examination of the readings just preceding and following the points marked by an asterisk will show that the movement of a column was much slower at these points than the average motion per minute. At the points preceding, the column certainly *seemed* to be in a condition of strain, as if it were acted upon by a force which tended to push it upwards until the film was broken.

(e) The tendency of a pulsatory movement of the mercurial column to become harmonic in its character seems to vary inversely as the time required for the completion of an entire cycle, that is, the slower the change of temperature, the greater the tendency to develop a real harmonic movement. Hence the probability of an error of reading, due to this cause, is much greater for very slow than for moderately rapid changes of temperature, since when the column has remained apparently stationary for a long time, we naturally conclude that the real stationary point has been reached. Observations of this class are, however, usually complicated with the question of the relative effect of the unknown previous thermal condition of the mercurial column and of the glass stem, in producing harmonic pulsations.

The observations upon which the conclusions reached in this paper rest, were made under such conditions in regard to temperature as were available at that time. Since the completion of the Shannon Physical Laboratory, a new series of observations has been made under more favorable conditions.

Before proceeding to a discussion of the results of this investigation, it may be well to give a brief description of the room in this building in which a fifty-foot unit of length is to be installed and which now contains all the apparatus employed in the investigations relating to standards of length. This com-

paring room is 58 feet in length, 30 feet in width and 16 feet in height. The walls of the room are of brick and eight inches in thickness. Between these walls and the walls of the main building, which are of brick and eighteen inches in thickness with an air space of two inches, there is a clear space of two feet on the four sides. Between the ceiling and the floor of the Physical Laboratory in the second story there is a clear space of three feet. The cellar has a height of seven and one-fourth feet. It has a cement bottom five inches thick. This room has the dimensions of the main building. Communications with the open space which surrounds the comparing room are made through the floor by means of large pipes of galvanized iron. A free circulatian of air around the room can, therefore, be maintained.

The comparing room is lighted by five sets of double windows in each wall of the building on the north side. Communications with the space between the walls is made by means of two sets of double doors extending nearly to the ceiling. The windows in the outside walls of the building have close-fitting wood shutters. The inner room may, therefore, be made a closed room, or, when desired, free communication may be made between the room and the air-space with which it is surrounded.

Different systems are employed for producing and for controlling any desired temperature. A given temperature is obtained by means of an over-head system of steam circulation with means of control. When any desired temperature has been obtained, there is added to the ordinary means of control a system of hot air circulation known as the Sturtevant System. Steam is drawn from a 26 H. P. boiler and passed through a large number of coils of iron pipe enclosed in a wrought iron case. This case is placed in a room situated beneath the tower of the main building, and is known as the heat storage room. The double walls of this room are of great thickness. The escape of the heat upwards, is prevented by an asbestos ceiling. A coil of steam pipes which will bear a pressure of one hundred pounds, surrounds the walls on three sides.

The following connections are made with the Sturtevant blower with which the steam coils are connected:

(a) With the space between the floors over the comparing room.

(b) With the cellar, by means of 12 inch pipes extending the entire length north and south on both sides. These pipes have four openings on each side.

(c) With the air space surrounding the inner room, by means of openings which communicate with the pipes in the cellar.

The heated air in the storage room is drawn through the iron case over the steam tubes and delivered wherever it is needed in order to maintain a constant temperature in the comparing room. It will be seen that either of the inner walls, the floor or the ceiling, can be heated to any required temperature at will, or that all can be so heated at the same time. The blower is driven by a 12 H. P. engine at about 600 revolutions per minute.

The Laboratory is heated by steam. The steam and hot air systems are independent. It has been found that when both systems are in operation at the same time, about 12 or 15 lbs. of steam will do all of the work required except at an extremely low temperature. The Sturtevant system alone can be run on 10 lbs. By turning a damper in the Sturtevant system and opening one in an underground pipe which leads to the open air and terminates in an ice box, cold air can be delivered to any part of the building at the rate and quantity desired.

It will be observed that the object sought to be gained in the construction of this comparing room has been not so much to secure a constant natural temperature, as to produce any required temperature and then to maintain this temperature until the complete effect of this condition in any particular investigation has been produced. It has been found possible to vary the conditions in such a manner as to eliminate a large share of the errors to which metrological observations are ordinarily subject.

Even with the imperfect means of temperature-control, available before the removal to the new laboratory, the increase of precision secured by the methods employed to eliminate the various classes of errors to which comparisons of standards of length are liable, was sufficiently great to justify the more elaborate equipment in the new building. Formerly it was found impossible to avoid errors having a maximum value of about four mikrons. This range of error has now been reduced to about one mikron. In a series of comparisons extending from October 28, 1888, to February 26, 1889, and covering a range of temperature extending from minus 13° F. to plus 100°, the deviation from the mean value of the determined relation at 62° between the two standards compared, in no case exceeds eight-tenths of a mikron; even when the reduction to 62° was made with a constant value of the relative co-efficient of expansion.

AMERICAN OPINIONS ON THE RELATION OF THE INFLUENZA EPIDEMIC TO METEOROLOGICAL CONDITIONS.

At the meeting of the American Medical Association held at Nashville, in May last, much interest was shown in the relation of meteorological conditions to the epidemic of influenza. A very valuable paper upon the subject was read by Dr. N. S. Davis, of Chicago, whose long professional career and clinical experience, combined with his well recognized habits of careful generalization, call special attention to the views expressed in it. The paper appears in full in the journal of the association June 7th, 1890. From it we quote: "When a disease thus suddenly attacks its victims in various parts of a city the same 24 or 48 hours, the victims being limited to no one class, age or sex, we are compelled to look for the efficient cause or causes to some vehicle or agency to which all are exposed. Only two such vehicles are known to exist in Chicago, viz: the atmosphere and water." * * * "During the period occupied by the recent epidemic of influenza and the co-incident high ratio of mortality from pneumonia, typhoid fever and gastro-intestinal affections, the water supplied to the inhabitants was both chemically and bacteriologically impure in a high degree." * * * "The prevalence of southwest winds during the months of December, January and February not only favored the flow of the contaminated water of the river into the lake—from which the city is supplied—but coupled with the unusually high temperature, it was bringing the atmosphere from over a wide and rich prairie country filled with the products of vegetable decomposition into all parts of the city." * * * "The atmospheric conditions throughout December, January and February in the city indicated an almost entire absence of ozone and hydrogen peroxide, and the presence of an unusual amount of free and albuminoid ammonia. Remembering that the epidemic influenza has pretty uniformly been accompanied by an increased mortality, attributed directly to it, while it is accompanied and followed for a considerable time by great impairment of hæmatous innervation and muscular strength, the question is suggested whether the efficient cause does not consist in some modification of the molecular arrangement and properties of those organic products designated as free and albuminoid ammonia, the inhalation of which impairs the function of the corpuscular element of the

blood and excites irritation in the nervous, pulmonary and mucous tissues of the body."

Dr. H. B. Baker of Michigan, furnished, in an exhaustive paper upon the same subject, an analysis of the meteorological conditions which have attended the epidemics of influenza from 1510 to 1837 as published by the Sydenham Society, together with data derived from other sources concerning those epidemics that have occurred since the latter year. It is a matter for regret that we have not space for the publication of this entire paper. The conclusions reached by Dr. Baker from his study of the subject are:

1. Epidemic influenza is the same disease as ordinary influenza; as is proved by facts observed and recorded by a large number of physicians.

2. Influenza is, to a very great degree, controlled by known atmospheric conditions, chiefly the temperature and humidity of the atmosphere, but wind has much influence, and probably also ozone and dust have influence.

3. The recent epidemic has followed, and preceding epidemics have followed, or been attended with, great extremes of temperature, high winds, winds from unusual directions, etc., dust, drouth, fogs, some tending to increased number of micro-organisms in the atmosphere, and all either to evaporation of the fluids of the air passages, or otherwise toward irritating the air passages. Briefly, the atmospheric conditions tending to cause influenza, are a high temperature followed rapidly by a low temperature, or by a wind which has the effect of rapidly cooling and drying everything exposed to the atmosphere, including the air passages of man.

4. Usual evaporation of the normal fluids of the air passages leaves the chlorides and other non-volatile constituents in excess at the place of evaporation, and sometimes this goes so far as to reduce below the normal the salts in the blood and urine, and this tends toward the precipitation of uric acid, and, consequently, toward neuralgia and rheumatism.

5. So far as influenza is an inflammatory disease, it is probably dependent upon micro-organisms, and upon those which are among the most wide-spread of all that affect the human organism; and they are not necessarily always of one species; and it may be the several varieties of the ordinary *Staphylococcus* and *Streptococcus Pyogenes* are active agents in influenza, and in other diseases which enter the body by way of the air

passages, or the alimentary canal. They are known to be present in osteo-myelitis.

6. Influenza supplies a way for the entrance to the body of micro-organisms which like *Staphylococcus Pyogenes* may cause one disease or another, or no serious trouble, according to conditions which, for instance, like co-existing injury to bone, may determine the occurrence of osteo-myelitis, or under other conditions, boils or carbuncles, or herpes may result. Erysipelas and cerebro-spinal meningitis have not infrequently, and pneumonia has still more frequently, followed influenza. The entrance of the micro-organisms which cause these diseases probably being facilitated by the same "influences" which cause influenza; but it is quite possible that in some instances the "influenza" has been the local action in the upper air passages, of one or more species of the micro-organisms which are believed to be the specific causes of the above named diseases.

7. Through similarity of causation, and probably by contributing to their causation, influenza is allied to several important diseases, and the mortality during the epidemic of it is chiefly from those other diseases.

8. Although influenza seems to be communicable, yet the onset of the disease usually affects so large a proportion of the people of a place, the people of a country and sometimes of widely separated countries, as to make it improbable that the disease occurs only by spreading from person to person. The occurrence of the disease in a similar manner on vessels at sea is also evidence in the same direction.

9. The micro-organisms which, thus far, have been found to bear a somewhat constant relation to influenza, bronchitis, and pneumonia have also been found in the air passages of a considerable proportion of people in health.

10. All of these facts are in harmony with the view that, through the influence of the unusual atmospheric conditions, a micro-organism which is generally present in the air passages of man, is able to multiply to an unusual extent, and to affect injuriously the person in whose air passages it exists, and to be spread about the community to an extent, and in numbers greater than in common.

11. One more fact [as I believe] is also explained by such an hypothesis: If the foregoing is the true explanation, then there should be, under ordinary conditions of the atmosphere, occasional slight changes which should be sufficient to cause influ-

enza in a few susceptible persons. It is a fact that influenza thus occurs in Michigan in every month of the year. It is also a fact that it sustains well-marked relations to certain conditions of the atmosphere.

CORRESPONDENCE.

OCEAN ICE AND COLD WEATHER

To the Editors: If floating ice in the Atlantic is the source of marked cooling in the United States and Europe during May and June it ought to be specially manifest this year, if ever. Ice has never been more plentiful nor for a longer period over the steamer tracks than during the past season. So far as is known to the writer, aside from a brief period in March, there has been no unusual cold, but quite the contrary.

M. A. Veeder.

Lyons, N. Y., June 12th, 1890.

CURRENT NOTE.

Rainfall of the Globe.—Mr. W. B. Tripp, at the May meeting of the Royal Meteorological Society, gave a comparative chronological account of some of the principal rainfall records. The earliest record is that of Paris which commenced in 1689. The English records began in 1726. The rainfall observations in the southern hemisphere do not extend over a very long period; at Adelaide they were commenced in 1839, but they do not go back further than 1866 for New Zealand. The greatest fall in any particular year at the stations given by the author was 160.9 inches at St. Bernard in 1839, and the least three inches at San Diego in California in 1863. By combining the stations in the northern and southern hemispheres the author finds that in recent times the years with the highest average rainfall were 1878, 1879 and 1883, and the years with the lowest average were 1854 and 1861.

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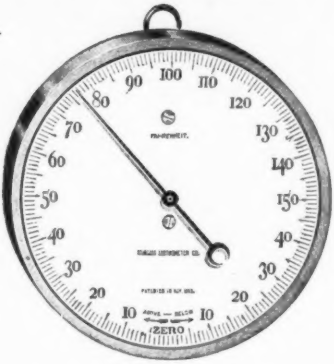

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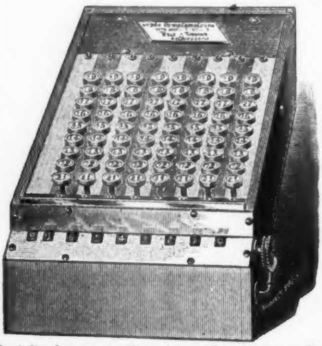

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